Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: Minerva Test Beam Detector in M-Test

Title: Lead Sheet Support and Hanger Bar Stress Analysis

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Abstract Summary:

As part of the Minerva Project, a detector is planned for use in the M-Test beamline. This detector will support planes of scintillator and absorber materials (both lead and steel absorbers). The entire detector will be mounted in a structural steel stand (see engineering note 141 for the calculations and design of the stand). This engineering note only addresses the support of the lead sheets and the lead hanger bar.

Applicable Codes: AISC 9th Edition

Lead Sheet Calculations:

Lead sheets from Rochester with dimensions of 57 inches by 33 inches by 0.080 inch thick will be used. Two sheets will be placed side by side (the 57 inch dimension will be vertical). One of the two sheets will be sheared to a width of 27 inches. This will give lead sheet plane dimensions of 60 inches wide by 57 inches vertical.

A second plane size will be made with one 57 by 33 sheet joined to a 57 by 29 inch wide sheet to give a lead plane of 62 inches wide by 57 inches vertical.

Making planes of two different sizes will allow the seams to be staggered as specified by the project physicists.

In each case, the lead is assumed to have a density of 720 pounds per cubic foot. With a plane thickness of 0.080 inch, the loading at the top of the lead (where it connects to the bottom of the hanger bar) is 1.9 pounds per inch.

Total weight of lead in a 57 inch by 62 inch plane is 117.8 pounds for a standard (not measured) lead density of 720 pounds per cubic foot.

Required tensile load (on a per inch of horizontal length basis) is 1.9 pounds per inch.

Assume the lead is attached to the hanger bar with epoxy. Use epoxy on both sides of the lead (so the lead is supported in double shear to reduce any pealing due to eccentricies). Try an epoxy surface that is one (1) inch long in the vertical position. This give a shear load of 1.9 psi divided between two surfaces for a resulting shear load of 0.95 psi.

3M Scotch-Weld Epoxy Adhesive 2216 B/A has a typical performance of 1500 psi for metal samples in double shear. This is about 1500 times stronger than needed to support the lead sheets.

<u>Hanger Bar Calculations</u>:
Hanger bar spans 110 inches. Load from the lead is 1.9 pounds per inch. Hanger bar is ½ inch thick and four inches deep on the ends, 1.9 inches where the lead attached to. Material is carbon steel with minimum yield strength of 30 ksi.

$L = 110$ inches
$b = 62$ inches
$a = c = 24$ inches
$w = 1.9$ pounds per inch

Image of the Lead Hanger Bar

Moment of Inertial in the strong axis, I_{xx} = 1/12 * ½ * 1.9^3 = 0.286 inch^4.

End Reactions, R1 and R2 = 58.9 pounds

Maximum Bending Moment is: M_{max} = R1 * (a + R1/2w) = 58.9 *(24+58.9/(2*1.9)) = 2326.55 in-pounds

Bending Stress, σ = My/I = 2226.55 in-pounds*2 inches / 2.667 in^4 = 1744 psi.

Check weak axis bending:
Width-thickness ratio, = b/t = 4 inches/.5 inches = 8
Limiting Width-Thickness Ratio for a compact section is 190 / SQRT (F_y) = 190 / SQRT (30) = 34.6

Limiting Width-Thickness Ratio for a non-compact section is 238 / SQRT (F_y) =43.4.

Since the Width-Thickness ratio of 8 does not exceed the criteria for a compact section, the hanger bar is considered a compact section.

Check un-braced length:
The un-braced length of the compression flange, L_b = 110 inches
This is a bar, so estimate the area of the compression flange as ½ inch wide by ½ inch tall for an area of ¼ square inches.

L_c = the lesser of 76*b_f/SQRT (F_y) or 20,000 / (d/A_f)*F_y (see eqn. F1-2)

$76*b_f/SQRT\ (F_y) = 76*.5/SQRT\ (30) = 6.9$ inches
$20{,}000 / (d/A_f)*F_y = 20{,}000 / (4/.5*.5)*30 = 41.6$ inches
Since $L_b > L_c$, the formula F1-8 is used to calculate the allowable stress.

$F_b = (12 \times 10^{\wedge 3} * C_b)/ 1* d / A_f$

$C_b = 1.0$ since the bending moment is larger than it is at the ends.
$A_f = .25$ square inches
$L = 110$ inches
$d = 4$ inches

$F_b = (12 \times 10^{\wedge 3} * 1.0)/ 110* 4 / .25 = 6.81$ ksi

Actual bending stress is 1.7 ksi, therefore, this is okay.

Check weld between the 0.080 inch thick bar for gluing the lead and the hanger bar:

Total load taken by the weld is 117 pounds. Assume a double sided fillet weld made with a 0.080 inch fillet leg (to match the thickness of the glue bar).

Assume fillet weld material yield strength of 60 ksi. Allowable tensile load is $0.30 * F_y = 20$ ksi.

Allowable Load, $P = 0.707 * w * l * 0.3 * F_y$ for each side of the weld.

Since this is a double sided weld, and the allowable load has got to be at least 117 pound, solving for the required length, l:

$l = P / (.0707* w * 0.3 * F_y * 2) = 117$ pounds / (0.707 * 0.080 inch * 0.3 * 60,000 pounds per square inch * 2 sides) = 0.0575 inches.

If the glue bar was welded to the hanger bar using an intermittent stitch weld of one inch every four inches, this will substantially exceed the required weld amount.